PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
H01Q 1/38

A1

(11) International Publication Number: WO 96/10276

(43) International Publication Date: 4 April 1996 (04.04.96)

(21) International Application Number: PCT/US95/12438

(22) International Filing Date: 27 September 1995 (27.09.95)

(30) Priority Data:
08/314,165 28 September 1994 (28.09.94) US

(71) Applicant: WIRELESS ACCESS INCORPORATED [US/US]; 2101 Tasman Drive, Santa Clara, CA 95054 (US).

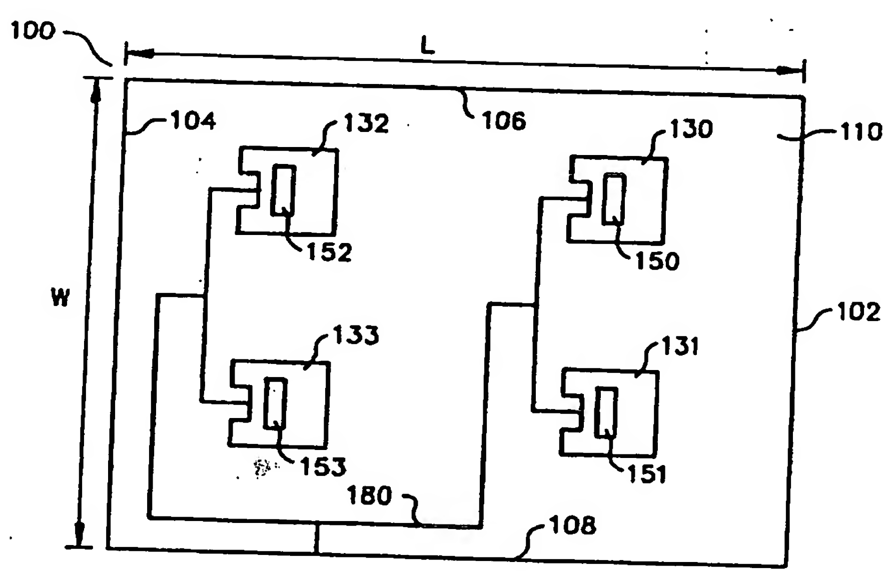
(72) Inventor: SANAD, Mohamed, S.; 3650 Buckley Street #512, Santa Clara, CA 95051 (US).

(74) Agents: MASCHOFF, Kurt, M. et al.; Townsend and Townsend and Crew, Steuart Street Tower, 20th floor, One Market Plaza, San Francisco, CA 94105 (US).

(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TT, UA, UG, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, MW, SD, SZ, UG).

Published
With international search report.

(54) Title: RING MICROSTRIP ANTENNA ARRAY



(57) Abstract

A ring microstrip antenna array (100) has a reduced size while exhibiting directional radiation characteristics and shows minimal degradation in performance when operated in close proximity to other electronics or the human body. The microstrip antenna array (100) includes a ground plane element (120) and a plurality of radiating patches (130-133), each made of conductive material, and a dielectric layer (110) positioned between the ground plane element (120) and the radiating patches (130-133), which together form a rectangular array. Each of the radiating patches (130-133) has two side edges (162, 164), a main radiating edge (160), and a base edge (166). All of the patches are oriented in the same direction. A short circuit (142, 144) provided along the base edge (166) of each of the patches creates a "mirror" image of each radiating patch relative to the base edge. The base edge may be fully shorted, or may be shorted along only a portion or selected portions of the edge.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	GB	United Kingdom	MR	Mauritania
AU	Australia	GE	Georgia	MW	Malawi
BB	Barbados	GN	Guinea	NE	Niger
BE	Belgium	GR	Greece	NL	Netherlands
BF	Burkina Faso	HU	Hungary	NO	Norway
BG	Bulgaria	IE	Ireland	NZ	New Zealand
BJ	Benin	IT	Italy	PL	Poland
BR	Brazil	JP	Japan	PT	Portugal
BY	Belarus	KE	Kenya	RO	Romania
CA	Canada	KG	Kyrgystan	RU	Russian Federation
CF	Central African Republic	KP	Democratic People's Republic of Korea	SD	Sudan
CG	Congo			SE	Sweden
CH	Switzerland	KR	Republic of Korea	SI	Slovenia
CI	Côte d'Ivoire	KZ	Kazakhstan	SK	Slovakia
CM	Cameroon	LI	Liechtenstein	SN	Senegal
CN	China	LK	Sri Lanka	TD	Chad
CS	Czechoslovakia	LU	Luxembourg	TG	Togo
CZ	Czech Republic	LV	Latvia	TJ	Tajikistan
DE	Germany	MC	Monaco	TT	Trinidad and Tobago
DK	Denmark	MD	Republic of Moldova	UA	Ukraine
ES	Spain	MG	Madagascar	US	United States of America
FI	Finland	ML	Mali	UZ	Uzbekistan
FR	France	MN	Mongolia	VN	Viet Nam
GA	Gabon				

RING MICROSTRIP ANTENNA ARRAY

BACKGROUND OF THE INVENTION

The present invention relates to small microstrip antennas for use in electronic devices. Particularly, the invention relates to microstrip antennas arrays suitable for use in portable electronic devices, such as base stations which require high directivity while operating in close proximity to humans or other electronic equipment. The antenna must operate while positioned in a variety of orientations, yet must be small enough to fit within small spaces, such as within a hand-held base unit.

Advances in digital and radio electronics have resulted in the production of a new breed of communications equipment posing special problems for antenna designers. These systems are typically small in size and may be easily carried by a user. Some of these systems, such as a portable base communications unit, require high directivity in order to function properly. These units are decreasing in size to the point that they may fit within small, hand-held packages. As a result, these antennas are subjected to increased radiation and "body effect" from the proximity of humans or

electronic equipment. "Body effect" can alter an antenna's resonant frequency as well as its gain.

In addition, the small size of today's communications equipment dictates that any antenna used must have a small overall size and a low profile. Further, it is desirable to utilize an antenna that is inexpensive to manufacture and that has characteristics which allow it to be tuned for use in a variety of applications.

Microstrip antenna arrays have been found to be useful alternatives for applications requiring a small and particularly thin overall size. A microstrip antenna array comprises a dielectric sandwiched between a conductive ground plane and a plurality of planar radiating patches. These patches are placed in arrays of varying dimensions in order to achieve desired performance characteristics. The patches in a typical microstrip antenna array are often a half wavelength in size. The patches in these arrays frequently are positioned up to one half wavelength apart, resulting in a large overall array size. Each of the patches in the array is energized via a feed scheme. One feed scheme for these microstrip arrays involves placing another layer above the radiating patches. Pin connections from striplines formed on the layer above the patches are then used to connect each patch. Alternatively, microstrip feed lines have been used. However, the positioning of these feed lines poses a difficult problem for designers, as the line must be properly attached to each radiating patch in order to achieve the needed overall input impedance.

Many different geometries for microstrip antenna arrays have been developed with resulting differences in radiation patterns and resonant frequencies. For example, many approaches are shown in the HANDBOOK OF MICROSTRIP ANTENNAS, James and Hall, eds., Peter Peregrinus Ltd., London, UK, 1989, pp. 35-37 and Chaps. 11-13.

Although these conventional microstrip antenna arrays have many advantageous characteristics, they do not meet the special demands of today's communications electronics for several reasons: they are vulnerable to human body

effects; they are difficult to tune without changing the overall shape or size of the dielectric or radiators; they are typically too large to fit within small communications devices when designed for operation at frequencies of interest, typically below 1 GHz; and, finally, complexities involved in designing feed arrangements for the array detract from the otherwise simple and inexpensive manufacture of these arrays.

Accordingly, what is needed is a microstrip antenna array of a design having a reduced size which has a low resistance to human body effect. It would be a further advantage to provide such an antenna with advanced tuning capabilities while remaining relatively inexpensive to manufacture. Finally, it would be desirable to provide such an array having a simplified feed scheme.

SUMMARY OF THE INVENTION

According to the invention, a ring microstrip antenna array includes a ground plane element and a plurality of radiating patches, each made of conductive material, and a dielectric layer positioned between the ground plane element and the radiating patches, which together form a rectangular array. Each of the radiating patches has two side edges, a main radiating edge and a base edge. All of the patches are oriented in the same direction. According to the invention, a short circuit provided along the base edge of each of the patches creates a "mirror" image of each radiating patch relative to the base edge. The base edge may be fully shorted, or in accordance with the invention may be shorted along only a portion or selected portions of the edge, as is discussed in the co-pending patent application Serial No. 08/049,514, entitled "A SMALL MICROSTRIP ANTENNA HAVING A PARTIAL SHORT CIRCUIT", by Mohamed S. Sanad, filed on April 19, 1993, and incorporated herein by reference.

Each radiating patch also includes a ring area cut-out from the patch, exposing a portion of the dielectric material underneath the radiating patch. The ring may have a rectangular shape, as disclosed in the co-pending patent application, Serial No. 08/049,560, entitled "A SMALL, DOUBLE

RING MICROSTRIP ANTENNA", by Mohamed S. Sanad, filed on April 19, 1993, and incorporated herein by reference. The ring may also have a triangular, circular, diamond, or other shape, as disclosed in the co-pending patent application, Serial No. 08/281,874, entitled "DOUBLE RING MICROSTRIP ANTENNAS", by Mohamed S. Sanad, filed on July 28, 1994, and incorporated herein by reference.

In one embodiment, the array consists of four radiating patches arranged in a two by two array formation, each patch having a rectangular ring formed within it. All of the patches are energized via a microstrip feed line. Other embodiments include three by three arrays, four by four arrays, and two by four arrays of radiating patches. Those skilled in the art will appreciate that other array sizes are also anticipated by the present invention. Other shapes may also be used. For example, in one specific embodiment, a microstrip array may be formed on a cylindrical or spherical surface. Other shapes and sizes of the antenna array will allow it to be used in a wide range of communication equipment.

For a fuller understanding of the nature and advantages of the invention, reference should be made to the ensuing description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a top view of one embodiment of a ring microstrip antenna array according to the present invention;

Fig. 2 is a side view of the ring microstrip antenna array of Fig. 1;

Fig. 3 is a cut-away view of the ring microstrip antenna array of Fig. 1 showing a single radiating patch;

Fig. 4 is a simplified top view of one specific embodiment of a ring microstrip antenna array according to the present invention;

Fig. 5 is a simplified top view of another specific embodiment of a ring microstrip antenna array according to the present invention;

Fig. 6 is a simplified top view of another specific embodiment of a ring microstrip antenna array according to the present invention;

Fig. 7 is a simplified top view of another specific embodiment of a ring microstrip antenna array according to the present invention; and

Fig. 8 is a perspective view of one embodiment of a cylindrical ring microstrip antenna array according to the present invention.

DESCRIPTION OF SPECIFIC EMBODIMENTS

Referring now to Fig. 1, a view of one specific embodiment of a ring microstrip antenna array 100 is shown. In this specific embodiment, four radiating patches 130-133 are positioned on top of a dielectric layer 110, which in turn is positioned above a conductive ground plane element 120. The radiating patches 130-133 are aligned in a two-by-two array, and are all oriented in the same direction, i.e., the primary radiating edge of each patch is oriented toward the primary radiating edge 102 of the array. Each of the patches 130-133 is energized via a microstrip feed line 104 which is powered from a feed source located off the antenna 100. The entire structure, for reasons which will be explained, has a significantly smaller size than previous microstrip arrays. Microstrip arrays according to the present invention enjoy small sizes while exhibiting good directivity and other desirable characteristics. Further, as will be discussed, the microstrip feed scheme used simplifies the construction of these ring microstrip antenna arrays, as some of the precision and additional structural complexity required in previous arrays are eliminated by the present invention.

Referring now to Fig. 2, a side view of the ring microstrip antenna array 100 of Fig. 1 is shown. The dielectric layer 100 has a thickness W_D. For most applications, it is preferred that the dielectric layer 110 is

between 40 and 100 mils thick. In a currently preferred embodiment, the dielectric layer 110 is 43 mils thick, and a dielectric such as Duroid 5880 is used. Duroid 5880 has a relative permittivity of approximately 2.2 and is available from Rogers Corporation, Chandler, Arizona. Each of the radiating patches 130-133 and the ground plane element 120 preferably has a thickness of 1.0 oz./m^2 of copper foil.

Details of the construction and operation of the array 100 will now be described by referring to Fig. 3, where a top view of one of the radiating patches 130 of Fig. 1 is shown in more detail. As shown, the radiating patch 130 is square or rectangular in shape. The patch 130 has a "ring" or aperture 150 formed in it. In the embodiment shown, the ring is rectangular. However, other shapes of rings may be used. For example, the use of triangular, circular, and diamond-shaped rings have been found to produce satisfactory results.

The patch 130 is also characterized in that it contains a short circuited edge 166 formed from two partially-shorted sections 142, 144. The two partially shorted sections each have widths W_{S1} and W_{S2}, the sum of which is less than the entire width of the patch W_P, leaving an open-circuited portion 146 having a width of W_{OS}. The shorted sections 142, 144 consist of a plurality of shorting posts 190a-190d which are used to electrically connect the radiating patch 130 to the conductive ground plane element 120. The shorting posts are formed of a conductive material, preferably copper, and may be formed by drilling or other means well known in the art. In one specific embodiment, the widths W_{S1}, W_{S2} of short circuit sections 142 and 144 are equal to about 8 mm on each side, where the overall width of the antenna W_A is 40 mm. The relative sizes of the shorted sections 142 and 144 may be selected to establish a selected resonant frequency and gain of the antenna.

In one embodiment, two shorting posts are evenly spaced within short circuit sections 142, 144. It has been found that the use of a greater number of shorting posts directly impacts the resonant frequency of the antenna. Further details regarding the use of a reduced number of

shorting posts in microstrip antennas is given in co-pending patent application Serial No. 08/281,875, entitled "SHORTING POSTS FOR MICROSTRIP ANTENNA", by Mohamed S. Sanad, filed on July 28, 1994, and incorporated herein by reference.

The use of the shorted sections 142, 144 in conjunction with the rectangular ring 150 results in a "mirror" effect, where a mirror image of the radiating patch 150 is created relative to the shorted edge 166. This effect allows the patch to function as a quarter wavelength radiator with a reduced size and with increased resistance to human body effect. In one specific embodiment, for a resonant frequency of 931.5 MHz, each resonant patch 130 is 41.5 mm long, more than 40% smaller than typical quarter wavelength radiators. It is believed that the increased coupling provided by these double ring patches allows each of the patches 130-133 to be positioned much closer together than in prior arrays.

Each radiating patch 130 of the antenna array 100 is energized via a microstrip feed line 180. The characteristics of these microstrip fed antennas are discussed in more detail in co-pending patent application, Serial No. 08/283,064, entitled "MICROSTRIP ANTENNA HAVING A MICROSTRIP FEED" by Mohamed S. Sanad, filed on 29 July 1994, and incorporated herein by reference. The microstrip feed line 180 is made of a conductive material such as the copper foil used to form the radiating patches. The line 180 has a width, which, in specific embodiments, is between 1 and 4 mm. The width of these feed lines 180 are chosen in order to achieve the desired input impedance of the array. The length of the feed line 180 is also chosen with input impedance in mind. Further, the length of the feed line 180 determines the phase at which each patch 130-133 resonates. In a specific embodiment, the length of the feed line 180 is also in the range of 1-4 mm. The feed line is positioned so that it connects to the patch 130 at the approximate center of the shorted edge 166. It is not necessary that the microstrip feed line 180 extend beyond the perimeter of the radiating patch 130 to obtain the requisite 50 ohm impedance. This is a

result of the partial short circuit which operates, in effect, to reduce coupling and losses in the feed lines 180.

Those skilled in the art will realize that the total length of each microstrip feed line 180, measured from the edge of the array to each radiating patch 130, may be designed to ensure that each patch is excited in phase. In one embodiment, the total feed path to each patch 130-133 is equal in length. In other embodiments, it may be desirable to energize different patches at different phases.

The width of the microstrip feed line 180 and its position along the shorted edge 166 of the patch 130 are selected in order to provide the 50 ohm input impedance. This input impedance value is dictated by the characteristic impedance of the microstrip transmission line attached to the antenna array 100. A number of other antenna characteristics apparent to one skilled in the art that affect the input impedance may also be taken into account in designing a specific antenna.

As illustrated, there are two short-circuited sections 142, 144. It is preferable that the first and second short-circuited sections are positioned as far from the microstrip feed line 180 as possible. However, in some embodiments, additional, short-circuited sections may be included, or their positioning varied on the partially shorted edge 166. The total width of all short-circuited sections (W_{S1} plus W_{S2}) is preferably between 10% and 90% of the total width of the patch W_P. It has been observed that changing the size of the shorted sections 142, 144 as a percentage of the total width of the patch W_P affects the input impedance. This feature may be useful in tuning the antenna.

It has been experimentally observed that if the total width of the shorted sections is less than 10% of the width of the patch, the patch will perform as a half wavelength patch. It is believed that the minimum total width of the shorted sections must be sufficient to provide a mirror image of the radiating patch relative to the shorted edge. In other words, the total width of the shorted sections should not be reduced below that width which provides such an

adequate mirror image. In order to meet the requisite input impedance of 50 ohms, the currently preferred width of the shorted sections is approximately 30% of the width of the antenna.

It has been found that the microstrip feed scheme described above has several advantages over previous feed schemes. For example, the position of the feed line 180 at the point it meets the patch 130 is less important in the present invention than in previous feed schemes. Previous schemes required the feedpoint to be placed well within the perimeter of the radiating patch to achieve an acceptable impedance. Thus, coaxial cables were often used to energize the antenna. This, of course, required an extension of the cable to the ground plane element, increasing the overall size of the antenna. Optimum positioning of a microstrip antenna can be difficult due to the protruding stub of a coaxial connection. For example, positioning the ground plane element adjacent to nearby metal surfaces may optimize the radiation pattern, but the stub of the coaxial connection can make such positioning difficult if not impossible. The coaxial connection could be accomplished from the radiating patch instead of the ground plane element; however, gain could be disadvantageously reduced. Furthermore, if an array is formed of microstrip antennas, use of coaxial connections is disadvantageous partly due to the size and space requirements of such connections and the large number of coaxial cables that would be required.

It has been suggested to provide a microstrip feed on the antenna itself that is inserted at the shorted edge and extends through the radiating patch to a feedpoint well within its perimeter. Conventionally, the feedpoint must be sufficiently distanced from the shorted edge in order to obtain an acceptable impedance. A major problem inherent in such microstrip feeds is unwanted radiation from the microstrip and cross-polarization of emitted radiation resulting in reduced gain and an impractical radiation pattern. This problem is related to the length of the microstrip feed and therefore a lengthy microstrip can emit

substantial amounts of unwanted radiation. Therefore, a microstrip feed is seldom used even though its use could reduce the cost and size of the antenna over a comparable coaxial connection, and simplify its connection to a circuit board.

Each of the patches 130-133 positioned on the antenna array of Fig. 1 will preferably have the same configuration as the one discussed in conjunction with Fig. 2. Those skilled in the art will appreciate that different configurations of patches may be utilized to achieve different performance characteristics. Experimentation has shown that antenna arrays constructed according to the present invention exhibit excellent directivity, low susceptibility to human body effect, and are significantly smaller in size than previous antenna arrays.

Each of the patches 130-133 may be positioned much closer to one another than in previous arrays. It is believed that this is made possible, in part, by the double ring effect of the shorted patches 130-133. The double ring increases the coupling of the patch, thereby allowing a closer placement of each patch to one another. For example, in one specific embodiment, the patches 130-133 may be positioned less than one quarter wavelength apart on the dielectric layer 110.

Referring now to Fig. 4, another specific embodiment of a ring microstrip array according to the present invention is shown. In this embodiment, a two by four array 200 of patches 230a-h is used. Each patch contains a triangular aperture 250 formed therein. It has been found that triangular-shaped rings produce results similar to rectangular-shaped rings such as those shown in Fig. 1. In this specific embodiment, a microstrip feed line 280 is placed on the dielectric layer 210 so that each of the patches 230a-h is excited in phase. Edge 202 is the primary radiating edge of the array 200.

Referring now to Fig. 5, another embodiment of a two by four array 300 is shown. In this embodiment, each of the patches 330a-h is oriented so that the primary radiating edge is edge 302. Again, a microstrip feed line 380 is fabricated

so that each patch is excited in phase. In the embodiment shown, each of the patches 330a-h has a circular ring 350 formed in it. Other shapes of rings may also be employed.

Referring now to Fig. 6, a three by three array 400 is shown. In this embodiment, edge 402 is the primary radiating edge and each of the patches 430a-i includes a diamond-shaped ring 450 formed therein. Fig. 7 depicts another specific embodiment of array. Specifically, a four by four array 500 is shown, where each of the patches 530a-p contain a rectangular aperture 550 formed within it. Those skilled in the art will appreciate that other shapes, dimensions, and configurations of arrays may also be implemented. For example, the nine by nine array of FIg. 7 may be implemented using triangular, diamond, or circular rings formed within the patch. The feed lines 580 may be created such that different patches will resonate at different phases.

Referring now to Fig. 8, yet another embodiment of a ring microstrip antenna array 600 is shown. In this embodiment, the array is formed on a cylindrical dielectric layer 610 which is then installed on a cylindrical surface 605. The cylindrical surface might be the exterior of a missile, pole, or the like. This configuration also achieves good directivity while occupying a smaller overall space than previous conformal arrays. Any shape or configuration of array or shape of ring 650 may be utilized.

As will be appreciated by those familiar with the art, the present invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. For example, the number, dimensions, or relative sizes of radiating patches may be modified in order to attain different resonant frequencies and bandwidths. It is believed that different frequencies and performance characteristics may be achieved by merely scaling the dimensions of the specific embodiments discussed herein.

Accordingly, the disclosure of the invention is intended to be illustrative, but not limiting, of the scope of the invention which is set forth in the following claims.

WHAT IS CLAIMED IS:

I Claim:

1. A ring microstrip antenna array comprising:

a ground plane element of an electrically-conductive material;

a dielectric layer positioned above the ground plane element;

a plurality of radiating patches of an electrically-conductive material positioned above the dielectric layer, said plurality of radiating patches arranged in an array formation; and

feed means positioned above said dielectric layer connecting each of said plurality of radiating patches to a feed source;

wherein each of said plurality of radiating patches defines a ring of a shape formed within a perimeter defined by said radiating patch, a portion of said dielectric layer being exposed by said ring.

2. The ring microstrip antenna array of claim 1 wherein each of said plurality of radiating patches defines a rectangular structure including a base edge, and wherein each of said plurality of radiating patches are aligned so that the base edges of said radiating patches are oriented in the same direction.

3. The ring microstrip antenna array of claim 1 wherein said base edge of each of said plurality of radiating patches includes a partial short circuit.

4. The ring microstrip antenna array of claim 3 wherein said partial short circuit comprises a plurality of shorting posts positioned along a portion of said base edge, electrically connecting said radiating patch with said ground plane element.

5. The ring microstrip antenna array of claim 1 wherein said feed means comprises a microstrip feed line.

6. The ring microstrip antenna array of claim 2 wherein said shape of said ring is a rectangle positioned parallel to said base edge.

7. The ring microstrip antenna array of claim 2 wherein said shape of said ring is an equilateral triangle having a first edge positioned parallel to said base edge.

8. The ring microstrip antenna array of claim 2 wherein said shape of said ring is a diamond having a corner nearest said base edge.

9. The ring microstrip antenna array of claim 2 wherein said shape of said ring is a circle.

10. The ring microstrip antenna array of claim 1 wherein said array formation is a two by two array.

11. A double ring microstrip antenna array comprising:

a ground plane element comprising a conductive material;

a plurality of radiating patches comprising a conductive material and having a shorted edge;

a dielectric layer positioned between the ground plane element and the plurality of radiating patches;

wherein each of said plurality of radiating patches further comprise

a shorted edge, formed from a plurality of shorting posts electrically connecting said plurality of radiating patches to said ground plane element, wherein said plurality of shorting posts are placed along a portion of said shorted edge,

a radiating edge positioned opposite said shorted edge,

a first side edge, and

a second side edge positioned opposite said first side edge; and

wherein each of said radiating patches defines a ring of a shape formed within a perimeter defined by said radiating patch, a portion of said dielectric layer being exposed by said ring;

wherein each of said plurality of radiating patches is electrically connected to a microstrip feed line.

12. The double ring microstrip antenna array of claim 11 wherein said portion of said shorted edge has a length between 10% to 90% of the total length of said shorted edge.

13. The double ring microstrip antenna array of claim 11 wherein said plurality of radiating patches are positioned on said dielectric layer in an array formation.

14. The double ring microstrip antenna array of claim 13 wherein said array formation is a two by two formation.

15. The double ring microstrip antenna array of claim 13 wherein said array formation is a four by four formation.

16. The double ring microstrip antenna array of claim 13 wherein said array formation is a two by four formation.

17. The double ring microstrip antenna array of claim 13 wherein said array formation is a three by three formation.

18. The double ring microstrip antenna array of claim 11 wherein said antenna array emits signals having a wavelength.

19. The double ring microstrip antenna array of claim 18 wherein each of said plurality of radiating patches are spaced apart from each other by a distance of less than one half of said wavelength.

20. The double ring microstrip antenna array of claim 11 wherein each of said plurality of radiating patches operate in phase.

FIG. 1

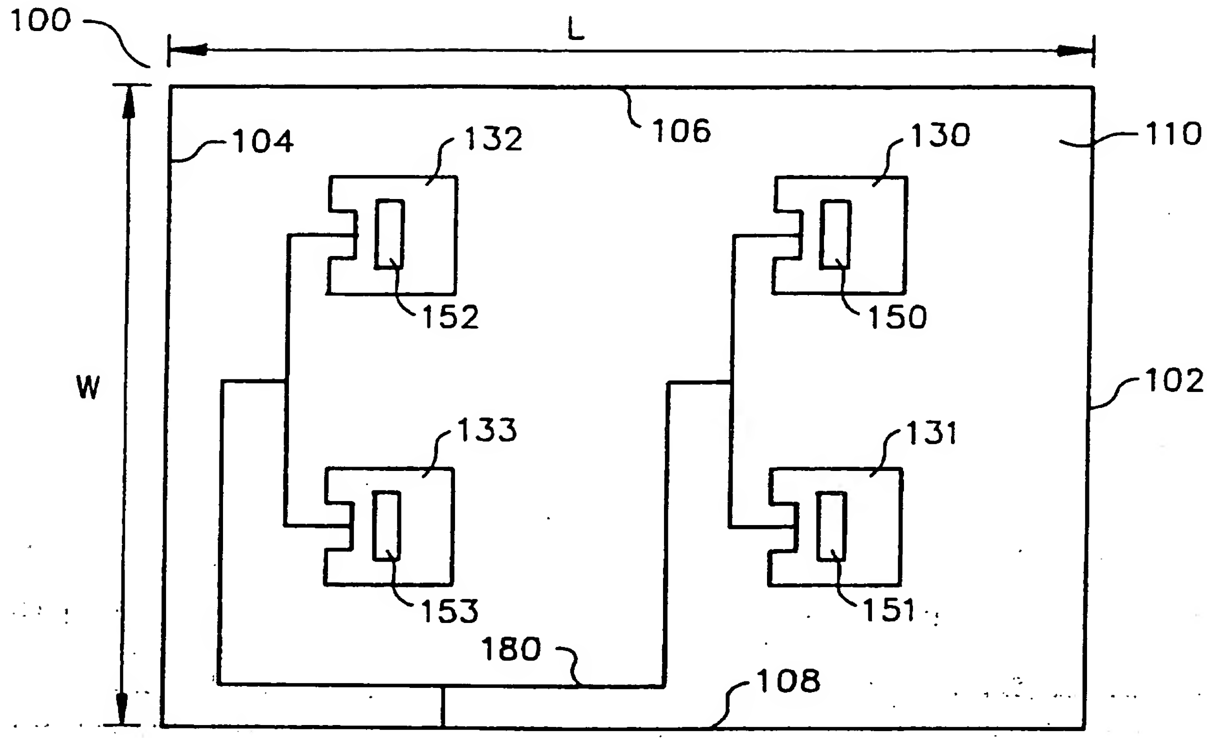


FIG. 2

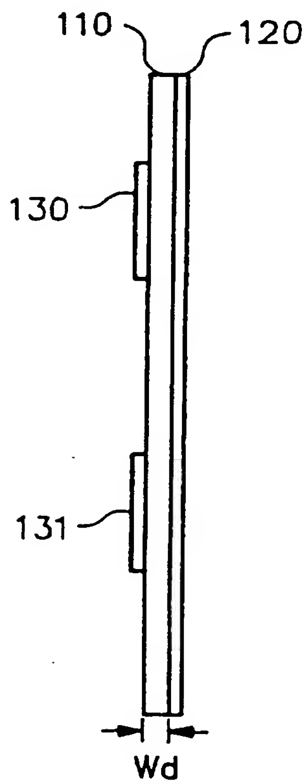
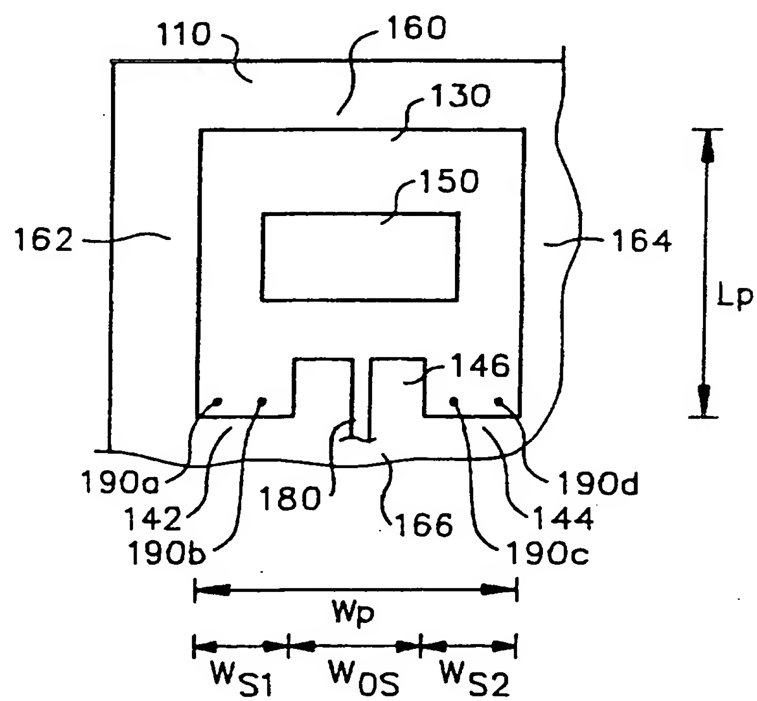


FIG. 3



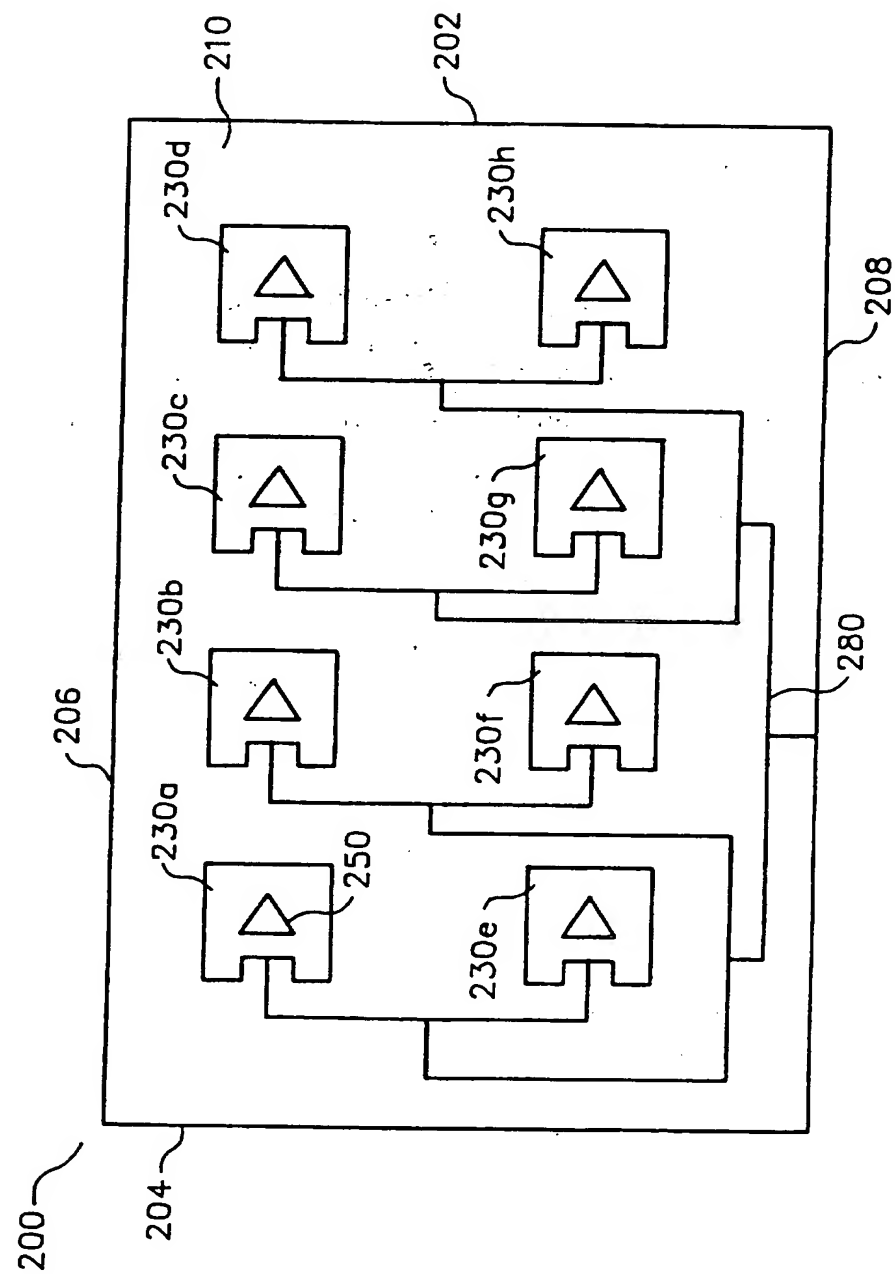

210
202
230d
230h
208
230c
230g
230b
230f
280
206
230a
250
230e
204
200

FIG. 4

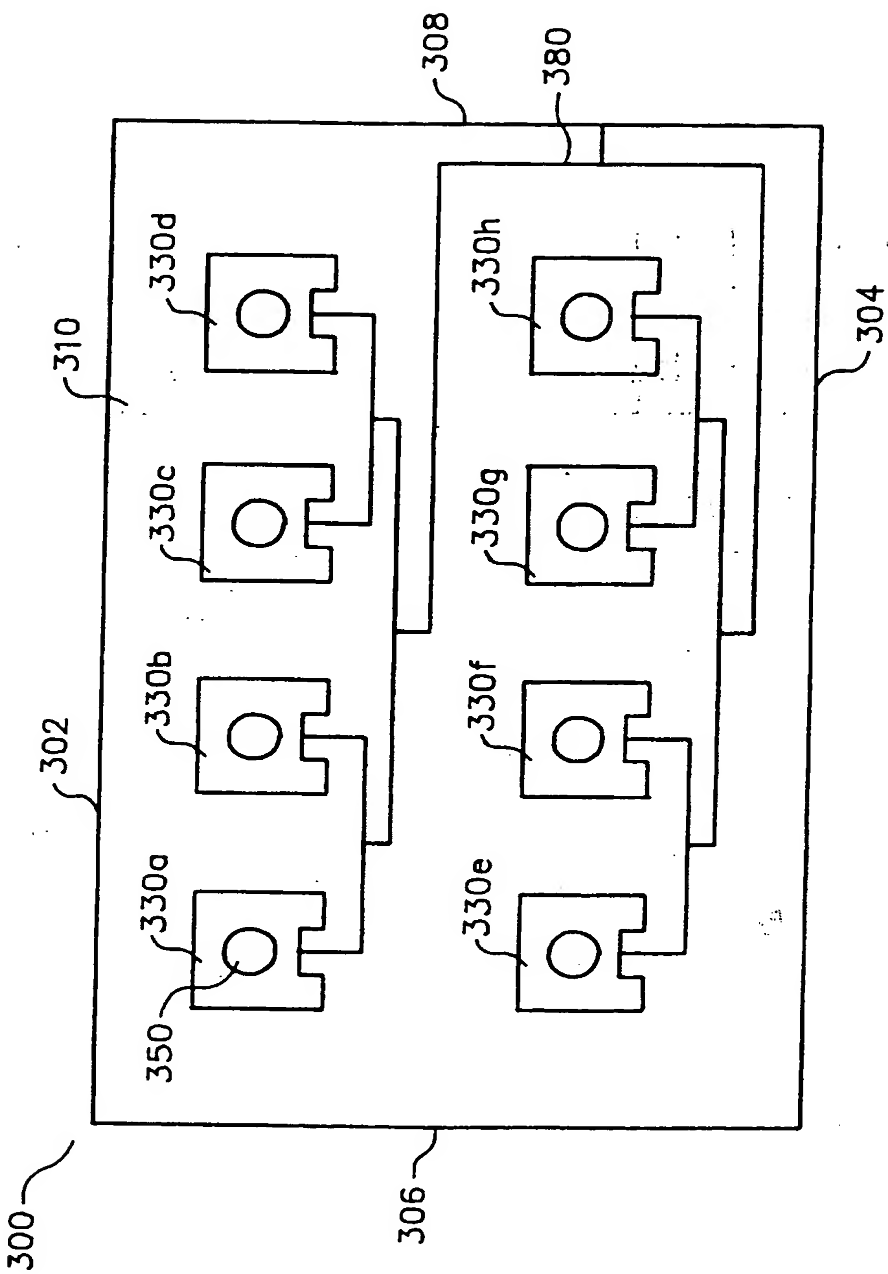

300
302
304
306
308
310
380
330a
330b
330c
330d
330e
330f
330g
330h
350

FIG. 5

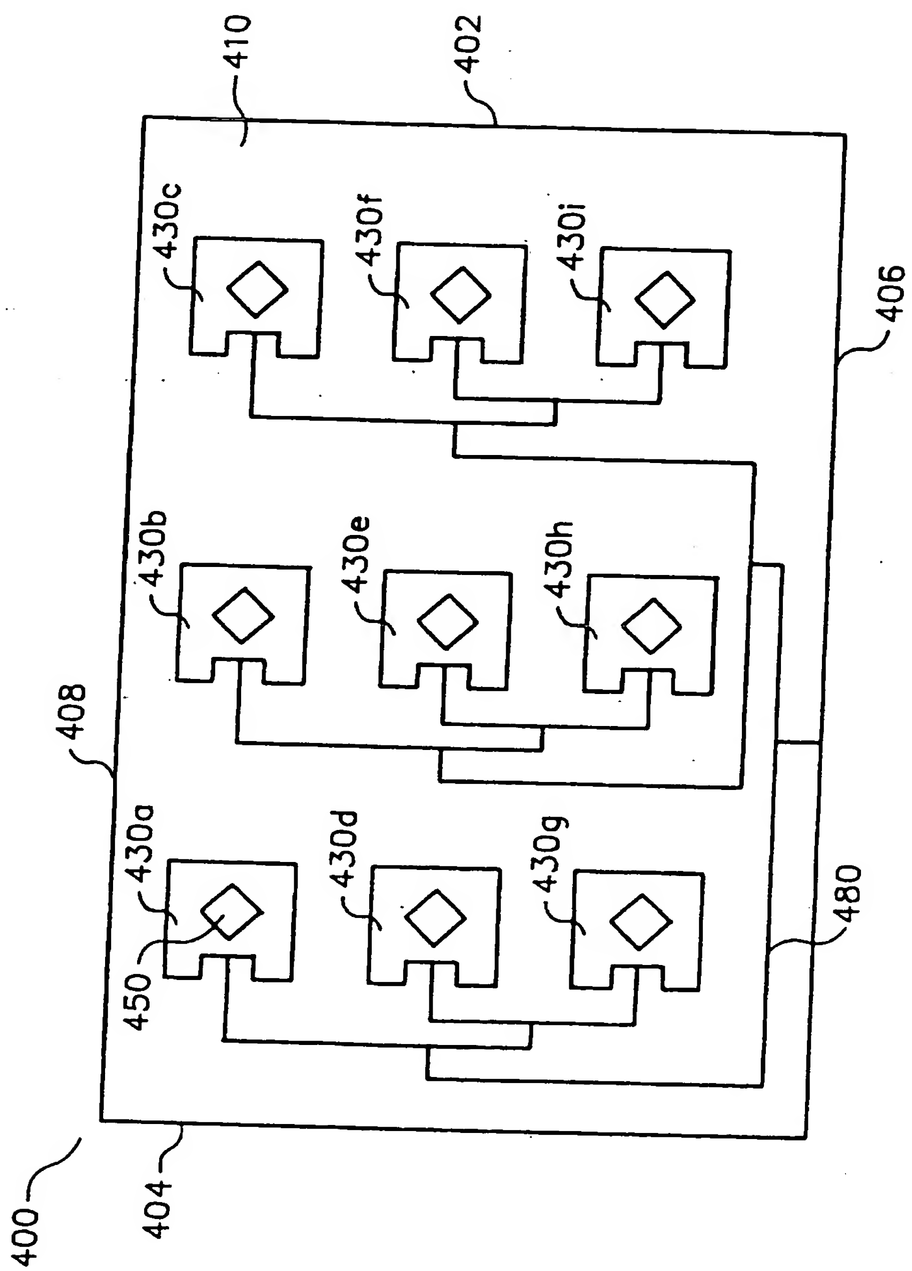

410
402
430c
430f
430i
406
430b
430e
430h
408
430a
430d
430g
480
450
400
404

FIG. 6

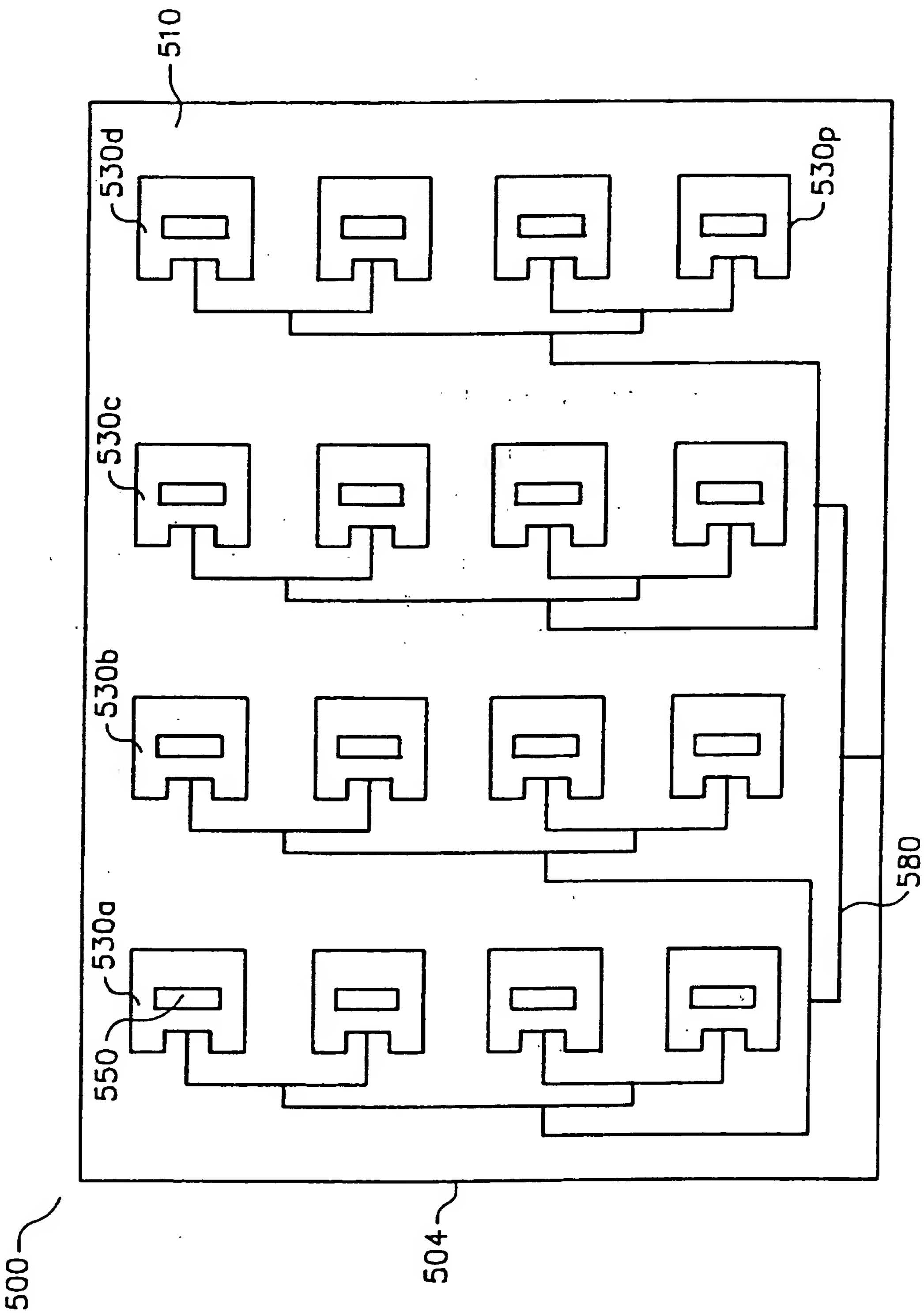
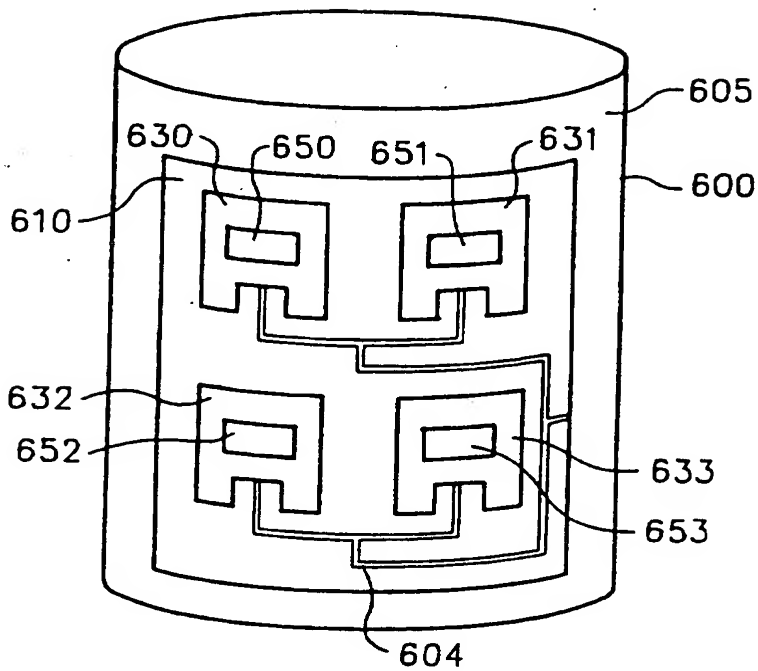


FIG. 7

FIG. 8



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/12438

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :HO1Q 1/38
US CL :343/700MS
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 343/700MS

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Handbook of Microstrip Antennas, Vol. 2, Peter Peregrinus Ltd.,1989, pp 24-39,1092-1105, see pages 26-28,1099-1102, especially Figures 19.27,19,33,19,34,19.40.	1-6,10-20
Y	US, A, 4,686,535 (LALEZARI) 11 AUGUST 1987, see Figure 3.	1-6,10-20
Y	Palanisamy et al, "Rectangular Ring and H-Shaped Microstrip Antennas--Alternatives to Rectangular Patch Antenna", IEEE publication, Vol. 21, No. 19, 1985, pp. 874-876, see Figure 1.	7-9

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 03 JANUARY 1996	Date of mailing of the international search report 11 JAN 1996
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer MICHAEL WIMER Telephone No. (703) 308-0956